Wavelength Doesn't Matter: Optical vs. X-ray Luminosities of Galaxy Clusters

Christopher J. Miller[1], Adrian L. Melott[2,3], and Robert C. Nichol[2]

ABSTRACT

We examine here the relationship between the total X-ray and optical luminosities of groups and clusters of galaxies taken from various samples in the literature. The clusters and groups were drawn from four different catalogs: (1) the Abell/ACO catalog, (2) the Edinburgh-Durham Cluster Catalog, (3) the RASS Bright Cluster Sample, and (4) galaxy groups selected from the CfA redshift survey. These catalogs represent a significant cross-section of cluster selection techniques as well as a wide range in mass scale and can be considered statistically independent. We have calculated new cluster X-ray and optical luminosities if not already available in the literature. Based on 126 systems, our analysis shows that the total optical luminosity of a cluster is directly proportional to the total X-ray luminosity over a wide mass range and across all four cluster samples studied herein. We also show that total cluster optical luminosity is a good indicator of cluster virial mass, whereas richness is not. Our results suggest that (1) the selection method of galaxy clusters may not be crucial, providing wider latitude in assembling catalogs, (2) the luminosity per baryon does not vary systematically between systems ranging from groups to very rich clusters. We propose that future optical catalogs of clusters use the total optical luminosity of a cluster, instead of galaxy richness, as luminosity appears to be a better measure of cluster mass and can be directly related to X–ray catalogs of clusters. This will also facilitate the first direct comparison between the growing number of X-ray and optical catalogs.

Subject headings: galaxies: clusters: general — large-scale structure of universe

[1]Department of Physics & Astronomy, University of Maine, Orono, ME 04469

[2]Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213

[3]Department of Physics & Astronomy,University of Kansas, Lawrence, KS 66045

1. Introduction

Clusters of galaxies are the most massive gravitationally bound and collapsed objects in the Universe and are important systems for studies of the formation and evolution of Large-Scale Structure (LSS) in the Universe. Their large mean spatial separations ($\sim 60 - 100 h_{50}^{-1}$Mpc) make them excellent tracers for LSS. The cosmological subfield of LSS is still in its infancy, with new and exciting discoveries occurring often. As large, all-sky surveys continue to catalog the heavens, galaxy clusters will remain the most efficient tool for mapping LSS. The importance of a complete map of LSS has become evident in some recent discoveries of how the internal properties of clusters can be affected by surrounding large-scale structure (Novikov et al. 1999; Loken et al. 1999; Miller et al. 1999). Additionally, clusters are often thought to be a "fair sample" of the mass in the Universe, and therefore useful for estimating the relative fractions of baryonic and "dark" matter (White *et al.* 1993; White and Fabian 1995; however see Qin and Wu 2000).

Most of the largest cluster surveys presently available in the astronomical literature have been constructed at optical wavelengths using galaxy population overdensities to define the individual clusters. The best known example of this technique is the Abell (1958) and Abell, Corwin, and Olowin (1989- hereafter ACO) optical cluster catalogs. Many researchers have discovered observational selection biases within these catalogs as a direct result of the criteria used in their creation (see *e.g.* Sutherland 1988; Efstathiou 1992). One of the more deserved critiques of the Abell/ACO catalogs is the inaccuracy of the the richness classifications (Lumsden et al. 1992; van Haarlem *et al.* 1997; White, Jones and Forman 1999). Richness has long been used as a classification in nearly all optically selected cluster catalogs – *i.e.* Abell, APM, EDCC, PDCS etc – yet it is rather unphysical to quantify cluster properties (such as mass, size, etc) based on a simple two–dimensional galaxy count within an arbitrary radius, to an arbitrary magnitude-limit with a local and/or global field galaxy count subtracted off. This ignores a significant amount of information contained in the individual galaxies (such as intrinsic brightness and color). Also, the richness of a cluster can be severely contaminated by projection effects as one goes to higher redshift.

In addition to these problems with galaxy richness, the recent discovery of "fossil groups" and "dark clusters" further illustrate the deficiencies of richness. Both Vikhlinin et al. (1999) and Romer et al. (1999) have discovered several examples of "fossil groups" which are the proposed relics of group formation and evolution *i.e.* all the galaxies in the group have 'cooled' and fully merged into one large galaxy in the center of the potential well. However, the X–ray emitting gas is still 'hot' and appears extended. Therefore, in an optical survey these systems appear to be one galaxy while in the X–rays they appear like

groups of galaxies. Clearly there is a dark–matter halo associated with such systems which would be completely missed in a classical, richness–limited survey. However, in an optical luminosity–based cluster survey, these systems would be included since the one central galaxy is typical many $L^{\star}$ in brightness (see Romer et al. 1999).

2. The Cluster Samples

We propose here dropping the notion of cluster richness in favor of total optical luminosity of a cluster; This can either be in a single passband or as a function of color *e.g.* constraining the color of the light to that appropriate for elliptical galaxies. Thus we allow the individual galaxy properties to re-enter the analysis. Currently, a large portion of the sky has reasonably accurate galaxy magnitudes through the APM/COSMOS galaxy catalog. This database covers the Southern galactic cap. There is a significant amount of work being done in the Northern hemisphere (*e.g.* the DPOSS survey (Djorgovski *et al.* 1999) and the Sloan Digital Sky Survey). Soon, we will have precise magnitude, and color information for most bright ($b_j \leq 20.5$) galaxies throughout the entire sky. We show in this work that future cluster identifications would be better quantified by total optical cluster luminosity than by richness.

2.1. The Edinburgh-Durham Cluster Catalog

The Edinburgh-Durham Cluster Catalog (Lumsden et al. 1992 -hereafter EDCC) was objectively selected from the Edinburgh/Durham Southern Galaxy Catalogue (EDSGC; Collins, Nichol & Lumsden 1992, 2000) which was built from machine-scans of 60 UK Schmidt photographic survey plates. In total, the EDCC contains over 700 galaxy overdensities covering over 1000deg^2 of the sky centered on the South Galactic Pole. The reader is referred to Lumsden *et al.* (1992) for details about the EDCC. We supplemented the optically–selected EDCC catalog with X–ray information taken from the ROSAT All-Sky Survey (RASS) Bright Source Catalog (Voges *et al.* 1999). This was achieved through cross–correlation of the EDCC centroids with the RASS–BSC positions. In Figure 1, we show our separation analysis for our EDCC–BSC sample which demonstrates a positive correlation (above that expected from random) for separations of less than 4 arcmins. Below 4 arcminutes, we would only expect a random 5.3 matching pairs while we see 53 matching pairs. Therefore, we use 4 arcminutes as our matching radius which should ensure that 90% of our these 53 EDCC clusters have a true X–ray companion. We then cut the EDCC–BSC sample to include clusters with a known redshift (Collins et al. 1995) as

well as those EDCC clusters coincident with an extended BSC source, thus guaranteeing minimal contamination from active galactic nuclei (AGN). These restrictions leave us with a subset of 20 EDCC–BSC clusters from the original 53 matches.

The X-ray luminosities of the EDCC–BSC clusters were computed as follows. First, the observed BSC count rate (counts per second) was converted to a flux (ergs per second per cm^2) by integrating a thermal bremsstrahlung spectrum of $\mathrm{T_e} = 5$keV and metallicity of 0.3 solar over the ROSAT PSPC response function ($0.1 \rightarrow 2.4$keV) and comparing this to the observed count rate (we corrected for absorption by the galactic neutral hydrogen using the data of Stark et al. 1990). Second, we corrected this aperture flux into a total cluster flux using a standard King profile ($r_c = 250h^{-1}$kpc and $\beta = 0.66$). Finally, our fluxes were converted into X-ray luminosities using $q_o = 0.5$, and $h_{50} = H_0/50$ (although we note that the choice of q_o makes little difference in our calculations).

The optical luminosities for these 20 EDCC clusters were calculated using photometry from the EDSGC which was calibrated to an accuracy of $\Delta m \simeq 0.1$ across the whole survey (see Collins et al. 2000). We first calculated the absolute magnitudes for all galaxies with $b_j \leq 20.5$ within each cluster using the same methods as Lumsden *et al.* (1992). We use $K(z) = 4.14z - 0.44z^2$ as the K-correction suitable for the b_j passband (Ellis 1983), and $A(b_j)$ as the extinction values taken from the Schlegel, Finkbeiner, and Davis (1998) reddening maps. Assuming that each galaxy lies at the distance of the cluster, we summed the individual galaxy luminosities to determine the local average background luminosity out to $20h_{50}^{-1}$Mpc around the cluster center. We then subtracted the local background from total cluster luminosity as determined within $2h_{50}^{-1}$Mpc of the cluster center. We applied apparent and absolute magnitude constraints and found only small ($\sim 10\%$) variations in our results. We also calculated the background using the average luminosity within the ring from $10h_{50}^{-1}$Mpc to $20h_{50}^{-1}$Mpc, effectively excluding the optical emissions from the clusters. Again, our final results only varied by $\sim 10\%$. From these analyses, we conclude that our methods are robust and we measure errors on L_o according to the variation in the choice of absolute magnitude limits (from $-24 < M_{b_j} < -21$). We present our optical and X-ray luminosities in Table 1.

In this work, we are studying a unique subset of the EDCC data, *i.e.* only those that have a redshift and extended X-ray emission in the RASS–BSC. Therefore, the sample presented in Table 1 has a complicated selection function since we have made two flux cuts (for the EDCC & BCS), a cut on X–ray extent and a cut on richness (since the high richness clusters have measured redshifts; Nichol et al. 1992). However, this selection function should not effect our analysis and results since we are simply using this sample to study the relationship of optical–to–X–ray luminosities of these systems and are presently

uninterested in the cross–comparison of these qualities between clusters.

2.2. The Abell/ACO Cluster sample

The second sample we have used is the Abell/ACO subset presented by Fritcsh & Buchert (1999, hereafter FB) who used a sample of 78 Abell/ACO clusters to create a fundamental plane in $L_{optical}$, L_{X-ray} and half-light radius and $R_{optical}$. They determined their optical luminosities after subtracting a local galaxy/photon distribution and applying a Schechter luminosity function with $M_{*} = -21.8$ and $\alpha = -1.25$. The individual galaxy magnitudes were taken from the COSMOS galaxy catalog. The X-ray luminosities were determined from ROSAT data using a Raymond-Smith code. More details can be found in FB. Unfortunately, FB do not provide the uncertainties on their data.

2.3. The RASS Bright Sample

Our third cluster sample is the ROSAT All-Sky Survey (RASS) Bright Sample which contains 130 clusters constructed from the ESO Key Program. This has since become the REFLEX cluster survey (Guzzo et al. 1999; Bohringer et al. 1998). The RASS Bright Sample is an X-ray selected cluster catalog. Extended X-ray sources in the RASS data were searched for over-densities in the galaxy distribution. This survey is count-rate limited in the ROSAT hard X-ray band. The RASS Bright Sample covers 2.5 steradian around the Southern Galactic Cap. We find 20 RASS clusters within a similar section of the sky as the EDSGC. However, due to the significantly different cluster selection and X-ray identification techniques between the RASS and EDCC surveys, we find only five clusters that are common to both. In other words, although the EDCC and RASS samples are in the same portion of the sky, the two samples remain nearly statistically independent. The X-ray luminosities for the RASS clusters are listed in De Grandi et al. (1999). We measured optical luminosities for the RASS clusters similarly to the EDCC clusters (see above) and present them in Table 1.

2.4. Galaxy Groups

Finally, we use data provided by Mahdavi *et al.* 1997 for poor galaxy groups. Mahdavi *et al.* studied 36 groups with at least five galaxy members selected from the Center for Astrophysics Redshift Survey (Ramella *et al.* 1995). Nine of these groups were found to

have definite X-ray emissions via RASS data. The optical properties were determined from Zwicky magnitudes listed in Ramella *et al.* and Mahdavi *et al.* fit Schechter luminosity functions (with $\alpha = 1$ and $M_B^* = -20.6$) to determine total optical luminosities to a limit of $M_B = -18.4$. We note that three groups in this sample are also $R = 0$ Abell clusters (although none are in the FB data as well).

3. Results

In Figure 2, we plot $log_{10}L_x$ versus $log_{10}L_o$ for the Abell/ACO clusters (Fig 2a), EDCC clusters (Fig 2b), galaxy groups (Fig 2c) and RASS clusters (Fig 2d). A correlation analysis indicates that the optical and X-ray luminosities are linearly related to 4.4σ, 3.1σ, 2.1σ, and 1.9σ significance levels respectively. [Note: if we remove the three "outliers" in the RASS sample, the significance rises to 3.2σ. This suggests that these points may not be clusters, but extended AGNs]. In all but the group sample, we also provide a robust best-fit line through the data points. The fit for the galaxy group is given by Mahdavi *et al.* (1997). In all cases, the slopes (listed in Fig. 2) are very close to unity, suggesting a simple proportionality survives the many procedural differences in the way these samples were selected and analyzed: *i.e.* Schechter functions were fit to some clusters, while for others, a simple sum of the individual galaxy luminosities was performed. Also, different optical wavelength windows were used *i.e.* b_j for Abell/ACO, EDCC, RASS, and m_{Zwicky} for the galaxy groups. Different aperture sizes within which magnitudes were summed were used: variable radius for Abell/ACO clusters, $2.0h_{50}^{-1}$Mpc for EDCC clusters and RASS clusters, and $0.4h_{50}^{-1}$Mpc for the galaxy groups.

At this point, it would be helpful to understand the role of the amplitude in Figure 2. However, we simply do not have enough information to constrain any more parameters than the slope. Some of the effects on the amplitude are more easily quantified, such as the solar luminosity used in the $L_o/L_\odot$ normalization or the Hubble constant used. The other procedural differences within these samples are more difficult to ascertain and correct for, such as the counting-radius used, magnitude-limits, etc. Therefore, at this point we would like to stress the importance of the simple proportionality between optical and X-ray cluster luminosities.

4. Discussion

The simplest possible assumption about the assembled contents and their emitted radiation seems to produce the observed results. This need not have been true. Optical luminosity measures the total optical radiation of all the stars in the clusters–which depends on the efficiency of star formation, the initial mass function of the stars formed, and the age of the populations. The X-ray emission depends on the mass, temperature, and the (square of the) density of the hot gas. We have studied a wide range of objects from galaxy groups up through rich clusters–several orders of magnitude in mass and luminosity. The trend which forms the basis of our result continues through this mass hierarchy.

This result could be the endpoint of a cosmic conspiracy of canceling effects. However, a simpler explanation is that "averaging" is effective, even on small scales. If systems as small as galaxy groups sample the stellar and gaseous phases of baryonic matter in the Universe as well as rich clusters, and the overall efficiency and mass range of star formation is about the same, and if the radiative efficiency of bremsstrahlung radiation is again about the same on average, then our result will follow. A slightly puzzling aspect of this result is that the larger systems are known to have higher velocity dispersions–and one would expect higher gas temperatures. One would think this would lead to greater X-ray luminosity per unit mass of gas.

Besides the cosmological implications, we must also consider how these results can be immediately applied in the construction of future cluster catalogs. With a proper normalization to the $L_x \propto L_o$ relation, we can very quickly and easily estimate cluster X-ray luminosities and masses using only the galaxy magnitudes and a minimal amount of spectroscopic and X-ray information. We need not perform extensive spectroscopic or X-ray observations of an entire cluster sample in order to analyze mass functions or correlation-functions and their dependence on cluster masses and X-ray luminosities.

As an example, we plot M_o vs L_o for the Abell/ACO clusters in Figure 3. Here, we have used cluster virial masses (M_{CV}) as published in Girardi *et al.* (1998) and the richness counts from the ACO catalog. The optical luminosities presented in FB were calculated within radii that included all of the light above the background. Therefore, we use those masses corresponding to the largest radii as published in Table 3 of Girardi *et al.* Figure 3 shows that optical luminosity linearly traces the total mass in galaxy clusters over a wide range, whereas we see a much weaker dependence of richness on mass. Therefore, L_o is much easier to correlate to mass than richness. Smail *et al.* (1997) have used more distant clusters to show that M/L varies little over a much smaller range of mass. We cannot provide any quantitative limits on M/L for clusters without more information on the FB optical luminosities.

In this paper, we have demonstrated that the total optical luminosity of clusters and groups of galaxies is correlated with both the X–ray luminosity and mass of these systems. This result is very important because, in the near future, there will be many new surveys of galaxies and clusters, *e.g.* DPOSS, REFLEX, SDSS, EIS, 2MASS *etc.*, and we will need objective methods to a) compare these different catalogs and b) relate the cluster properties to physically meaningful quantities. Optical cluster luminosities will be easy to compute from these digital catalogs and will allow us to directly relate optical cluster catalogs with X–ray–selected catalogs (*e.g.* REFLEX, EMSS, SHARC). Moreover, it is hoped that the optical luminosity of a cluster is more easily related to theoretical cluster research than the galaxy richness, since we have shown that the optical luminosity is simply probing the density in baryons in the cluster. It is appears that galaxy richness has a similar physical motivation.

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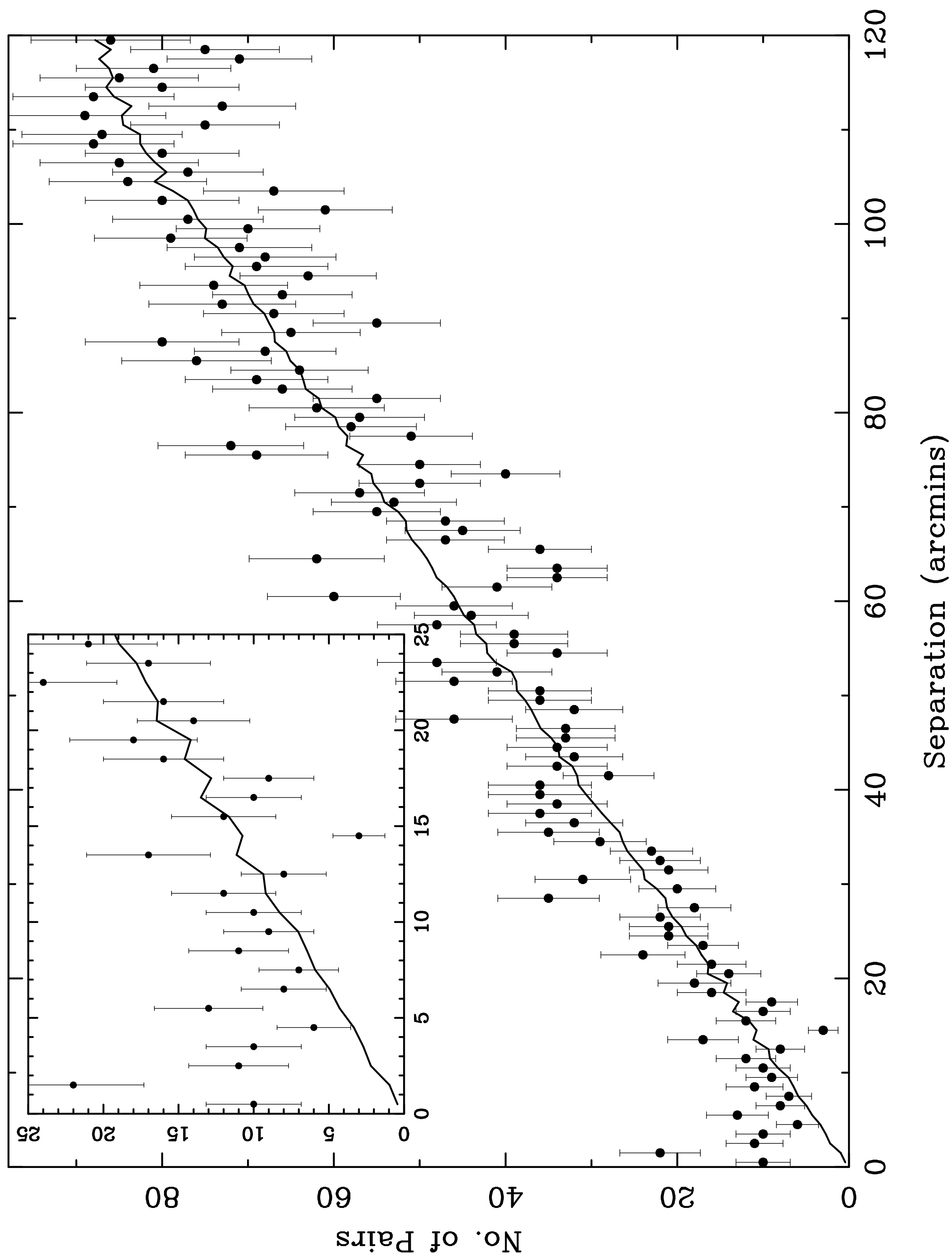

Fig. 1.— EDCC–BSC pair counts as a function of angle. A random sample would produce only 5.3 matching pairs below 4 arcmins while we see 53 matching pairs. Therefore, we use 4 arcminutes as our matching radius which should ensure that 90% of our EDCC clusters have a true X–ray companion.

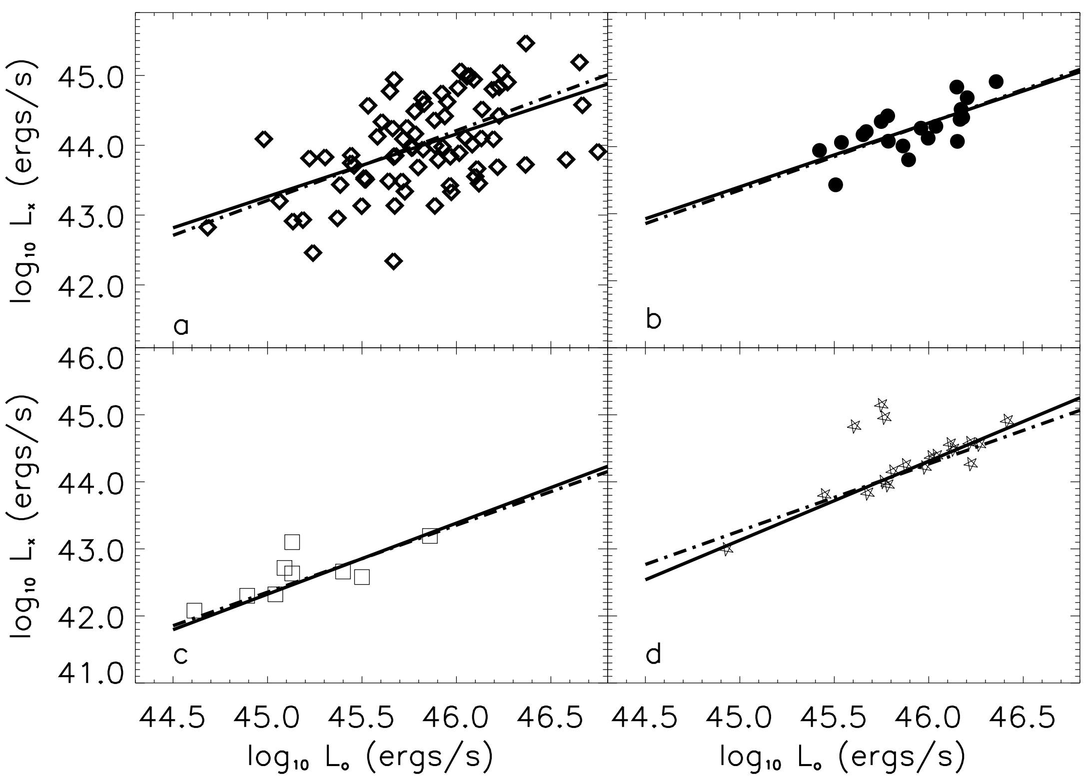

Fig. 2.— We plot $\log L_o$ vs. $\log L_x$ for the samples defined in Section 2. The error bars are excluded for reasons of clarity (although they are listed in Table 1). In each plot, the solid line corresponds to best-fit to the data. **(a)** is the Abell/ACO sample where $logL_x \propto logL_o^{0.90\pm0.17}$. **(b)** is the EDCC sample with $logL_x \propto logL_o^{0.95\pm0.22}$. **(c)** is the CfA group sample with $logL_x \propto logL_o^{1.06\pm0.11}$. **(d)** is the RASS sample with $logL_x \propto logL_o^{1.18\pm0.08}$. In each plot, the dashed-line corresponds to $logL_x \propto logL_o$.

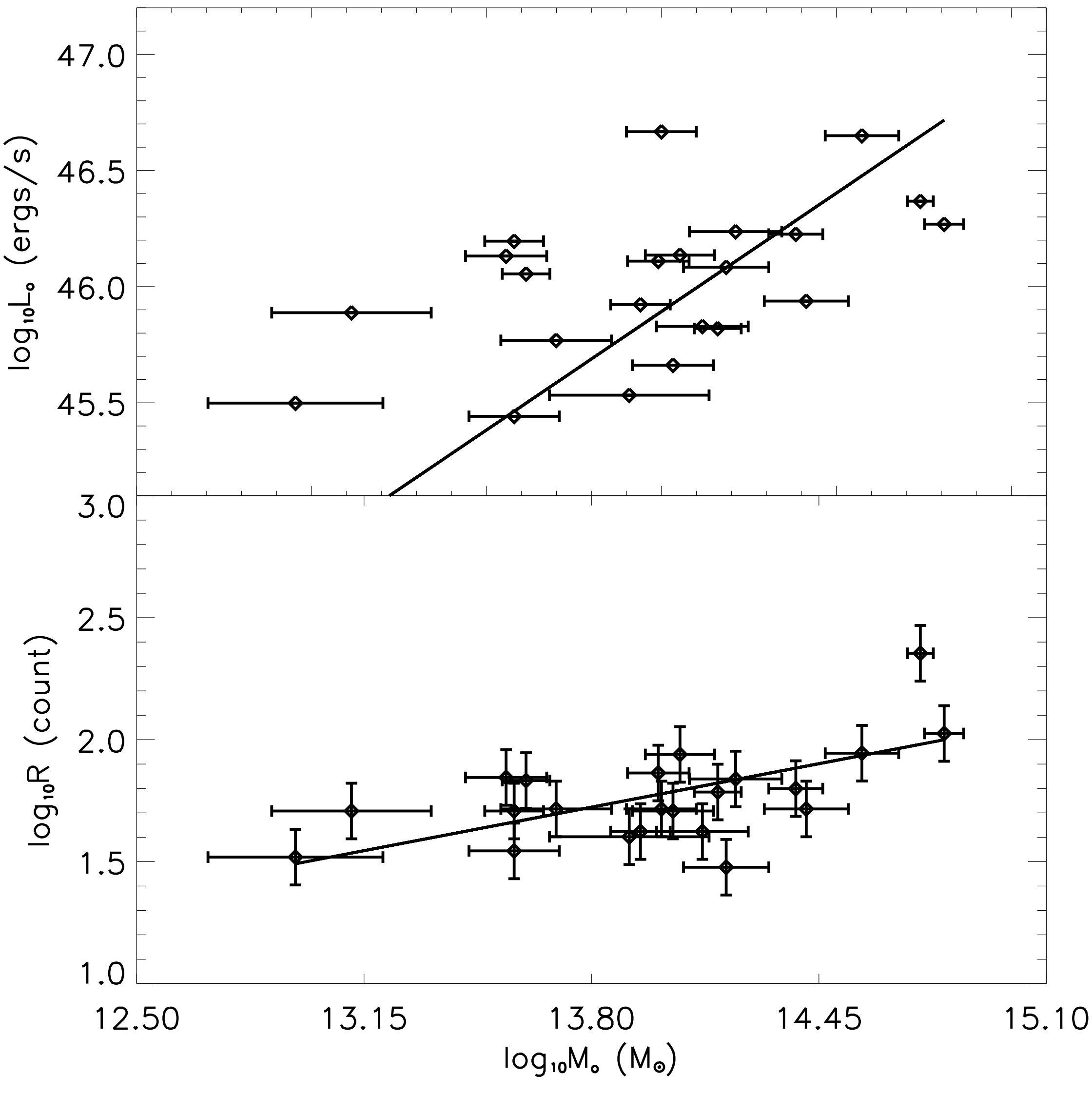

Fig. 3.— In the **top** figure, we plot L_o vs. M_o for the Abell/ACO clusters in the Abell/ACO sample. We used only those clusters with published virial masses (and uncertainties) in Girardi *et al.* (1998). The best fit line is $logL_o \propto logM_o^{1.02\pm0.07}$. In the **bottom** figure, we plot Richness counts (as specified in ACO) vs. M_o. The best fit line is $logR \propto logM_o^{0.27\pm0.06}$. The small slope in $logR$ vs. $logM_o$ makes correlating mass to richness more difficult than mass to L_o.

Table 1. **Cluster Luminosities**

Cluster Name	$L_o \times 10^{11}$ L$\odot$	$L_x \times 10^{44}$ h_{50}^{-2}ergs/s
EDCC 42	10.04 ± 0.08	5.373 ± 0.69
EDCC 127	9.19 ± 0.57	7.753 ± 0.95
EDCC 160	14.85 ± 0.21	9.351 ± 1.05
EDCC 197	2.10 ± 0.12	0.270 ± 0.15
EDCC 287	5.94 ± 0.68	1.888 ± 1.34
EDCC 320	1.73 ± 0.23	0.878 ± 0.41
EDCC 394	2.25 ± 0.22	1.157 ± 0.34
EDCC 400	9.88 ± 0.53	2.725 ± 1.11
EDCC 410	3.96 ± 0.24	2.881 ± 0.43
EDCC 438	3.99 ± 0.07	1.207 ± 0.78
EDCC 447	7.12 ± 0.30	2.012 ± 0.75
EDCC 485	3.66 ± 0.04	2.373 ± 0.82
EDCC 507	9.26 ± 0.62	1.200 ± 0.76
EDCC 520	9.68 ± 0.38	3.606 ± 1.63
EDCC 526	6.48 ± 0.13	1.338 ± 1.04
EDCC 576	2.93 ± 0.15	1.508 ± 1.06
EDCC 632	3.05 ± 0.37	1.679 ± 0.52
EDCC 699	9.57 ± 0.33	2.556 ± 2.47
EDCC 735	5.11 ± 0.13	0.638 ± 0.47
EDCC 758	4.77 ± 0.15	1.024 ± 0.32
RASS 001	1.84 ± 0.22	-
RASS 002	10.92 ± 0.05	-
RASS 003	4.22 ± 0.24	-
RASS 006	1.21 ± 0.05	-
RASS 007	3.11 ± 0.24	-
RASS 008	7.18 ± 0.30	-
RASS 010	8.83 ± 0.63	-
RASS 011	6.24 ± 0.44	-
RASS 015	6.74 ± 1.53	-
RASS 028	0.56 ± 0.72	-
RASS 030	3.82 ± 0.84	-
RASS 106	10.82 ± 0.01	-
RASS 109	8.50 ± 0.07	-

REFERENCES

Abell, G. O. 1958, ApJS, 3, 211

Abell, G. O., Corwin, H. G., Olowin, R. P. 1989, ApJS, 70, 1 (ACO)

Böhringer, H., *et al.* 1998, The Messenger, 94, 21

Collins, Nichol, & Lumsden 1992, MNRAS, 254, 295

Collins, C.A., Guzzo, L., Nichol, R.C., & Lumsden, S.L. 1995, MNRAS, 274, 1071

Collins, C.A., Lumsden, S.L. Nichol, R.C., ApJS, submitted

David, L., Forman, W., & Jones, C. 1999, ApJ, 519, 533

De Grandi, S., Bohringer, H., Guzzo, L., Molendi, S., Cinicarini, G., Collins, C., Cruddace, R., Neumann, D., Schindler, S., Schuecker, P., & Voges, W. 1999, ApJ, 514, 148

Djorgovski, S.G., Gal, R.R., Odewahn, S.C., de Carvalho, R.R., Brunner, R., Longo, G. and Scaramella, R. 1999, to appear in Wide Field Surveys in Cosmology, eds. S. Colombi and Y. Mellier

Efstathiou, G., Dalton, G.B., Maddox, S.J., & Sutherland, W. 1992, MNRAS, 257, 125

Ellis, R.S., 1983, in Jones, B.J.T., Jones, J.E., eds, Thr Origin and Evolution of Galaxies. Reidel, Dordrecht, p. 225

Fritsch, C. and Buchert T. 1999, A&A, 344, 759

Girardi, M., Giuricin, G., Mardirossian, F., Mezzetti, M., & Boschin, W. 1998, ApJ, 505, 74

Guzzo, L. *et al.* 1999, The Messenger, 95, 27

Loken, C., Melott, A.L., Miller. C.J. 1999, ApJ , 520, 5L

Lumsden, S.L. Nichol, R.C., Collins, C.A. and Guzzo, L. 1992, MNRAS, 258, 1

Mahdavi, A., Böhringer, H., Geller, M., & Ramella, M. 1997, ApJ 483, 68

Miller, C.J., Melott, A.L., and Gorman, P. 1999, ApJ, 526, L61

Novikov, D.I., Melott, A.L., Wilhite, B.C., Kaufman, M., Burns, J.O., Miller, C.J., and Batuski, D.J. 1999, MNRAS, 304, L5

Qin, B., and Wu, X. 2000 ApJ(Letters), in press (astro-ph/9912007)

Ramella, M., Geller, M., Huchra, J.P., & Thorstensen, J.R. 1996, AJ, 109, 1469

Romer, K., *et al.* 1999, ApJS in press, astro-ph/9907401

Schlegel, D.J., Finkbeiner, D.P., and Davis, M. 1998, ApJ, 500, 525

Stark, A.A., Gammie, C.F., Wilson, R.W., Balley, J., Linke, R.A., Heiles, C. & Hurwity, M. 1992, ApJS, 79, 77

Sutherland, W. 1988, MNRAS, 234, 159

van Haarlem, M.P., Frenk, C.S., & White, S.D.M. 1997, MNRAS, 287, 817

Vihklinin, ,A., McNamaram B.R., Hornstrup, A., Quintana, H., Forman, W., Jones, C., & Way, M. 1999, ApJ , 520, L1

Voges, W., *et al.* 1999, A&A, 349, 389

White, S.D.M., Navarro, J.F., Evrard, A., and Frenk, C.S. 1993, Nature, 366, 429

White, D. and Fabian, A. 1995, MNRAS, 273, 72

Table 1—Continued

Cluster Name	$L_o \times 10^{11}$ L$\odot$	$L_x \times 10^{44}$ h_{50}^{-2}ergs/s
RASS 110	2.64 ± 0.07	-
RASS 113	3.97 ± 0.20	-
RASS 115	10.70 ± 0.22	-
RASS 127	3.76 ± 0.21	-
RASS 128	3.67 ± 0.56	-
RASS 130	4.92 ± 0.74	-